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UREDINALES (RUST FUNGI) BIOTA OF THE PARQUE NACIONAL DO ITATIAIA, BRAZIL: AN ANALYSIS OF COMPOSITION, SPECIES DIVERSITY AND ALTITUDINAL DISTRIBUTION

Biota de Uredinales (Royas) del Parque Nacional do Itatiaia, Brasil: un análisis de la composición, diversidad de especies y distribución altitudinal

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ABSTRACT
The present study analyzed the composition, species diversity, and altitudinal distribution of rust fungi (Uredinales) collected in the Parque Nacional do Itatiaia, Brazil. Results were compared with other Atlantic Forest locations, the São Paulo Cerrado and some other tropical regions. The Uredinales collections were made over the course of two years, covering the states of Rio de Janeiro and Minas Gerais, from 500 to 2600m above the sea level. The Uredinales Biota is composed of 38 genera (32 teleomorphs and 6 anamorphs) and 207 species, 178 of which were teleomorphic and 29 anamorphic. The genera *Puccinia*, *Uromyces* and *Phakopsora* contained a high number of species (58% combined). A hundred and ninety-two hosts belonging to 63 botanical families were recorded. The rust/host ratio for ten of the richest families in number of species was 1:8. A high similarity (50%) was found between two altitudinal ranges. The results provide a strong additional argument for the need to preserve and continue studies in such areas.

Key words. Brazil, Diversity, Rust fungi, Parque Nacional do Itatiaia, Uredinales.

RESUMEN
Se analiza la composición, la diversidad de especies y la distribución altitudinal de las especies de hongos roya (Uredinales) recolectados en el Parque Nacional do Itatiaia, Brasil. Los resultados encontrados han sido comparados con otras localidades de la Floresta Atlántica y el Cerrado del estado de São Paulo, además de otras regiones tropicales. La colección de Uredinales se realizó durante dos años, cubriendo los estados de Rio de Janeiro y Minas Gerais, desde los 500 hasta 2600 metros sobre el nivel del mar. Los resultados muestran que la Biota de Uredinales del Parque está compuesta por 38 géneros (32 teliomorficos y 6 anamorfos) y 207 especies de las cuales 178 son teliomorficas y 29 anamorficas. Los géneros *Puccinia*, *Uromyces* y *Phakopsora* son los de mayor número de especies (58% en total). Se registraron 192

hospedantes con presencia de roya ubicados en 63 familias botánicas. La relación roya/hospedante para las diez familias botánicas más ricas en especies fue de 1:8. Se encontró una alta similitud (50%) entre los dos rangos altitudinales usados en el estudio. Estos resultados proveen un argumento adicional sobre la urgente necesidad de preservación y estudio de estas áreas.

Palabras clave. Brasil, Diversidad, Royas, Parque Nacional do Itatiaia, Uredinales.

INTRODUCTION

The Parque Nacional do Itatiaia (PARNA Itatiaia) is situated within the Atlantic Forest and the Mantiqueira mountain range and bounded by the States of Rio de Janeiro and Minas Gerais, Brazil. The park covers the municipalities of Alagoas, Bocaina de Minas and Itamonte, between parallels 22º19' and 22º45' South and meridians 44º15' and 44º50' West. When it was created in 1937, the park had an approximate area of 12,000 ha. Later, its area was expanded to about 30,000 ha (http://www.ibama.gov.br/parna_itatiaia). The regime of rainfall, temperature and historic colonization by plants promoted the emergence of an altitudinal and microclimatic profile that has decisively influenced its biodiversity. Thus, the unique features of PARNA Itatiaia stand out relative to its plant diversity and high degree of endemism (Safford 1999). According to the classification system of Veloso *et al*. (1991), the PARNA Itatiaia is composed of two forest formations: *Floresta Ombrofila Densa Montana*, (500-1500 MSL) and *Floresta Ombrofila Densa Alto Montana* (above 1500 MSL). The area of study also includes the vegetation refuges.

The Order Uredinales, commonly known as rust fungi, is one of the most numerous and important groups of phytopathogenic fungi. It is exclusively composed of obligate parasites with a broad spectrum of hosts, such as Pteridophyta, Pinophyta and Magnoliophyta (Pardo-Cardona 2000). This Order has an extensive worldwide distribution and is adapted to extreme climatic conditions. The life cycle of rust fungi is characterized by its diverse structures (spermogonia, two anamorphs, teleomorphs and basidiospores) and its plasticity (Hennen & Buriticá 1980). As a consequence of coevolution and the high specificity of certain species of pathogens to their hosts, any area having a high diversity of hosts often correlates with a high diversity of pathogens. It follows that the great diversity of plants and the high endemism of PARNA Itatiaia suggest a large diversity of highly specialized Uredinales species.

The oldest Uredinales collections from PARNA Itatiaia were made by Ernst Heinrish Georg Ule between 1883 and 1903. Materials collected by Ule were mainly studied by Paul Hennings (Hennings 1899), Paul Dietel (Dietel 1899) and Franz Otto Pazschke (Pazschke 1896) in Germany. These collections are currently deposited at the University of Hamburg Herbarium (HBG) (Friederichsen 1973). Between 1921 and 1922, Edward Willet Dorland Holway made the largest collection of rusts from Brazil, including materials from PARNA Itatiaia which were studied in the United States by H. S. Jackson (Jackson 1926-1932). These collections are deposited in the Arthur Herbarium (PUR) at Purdue University. However, these samples were collected sporadically and in a non-intensive way. Moreover, data, such as composition, species diversity, and altitudinal ranges in comparison with other areas, were absent. Therefore, this study aimed to update and increase the knowledge of Uredinales

species found at the Parque Nacional do Itatiaia, Brazil. To accomplish this, data on the composition, species diversity and altitudinal ranges of Uredinales were collected, analyzed and compared with other areas of the Atlantic Forest (Brazil) and with Cerrado areas of São Paulo State (Brazil), Colombia, Costa Rica and Southern Africa.

MATERIAL AND METHODS

First, an extensive review of the literature was conducted to become familiar with species of Uredinales previously reported for the Parque Nacional do Itatiaia (PARNA Itatiaia). Collections were then made over a two-year period, from July 2006 to June 2008, with a total of 13 expeditions, each lasting 5 days. Samples were collected from wild and exotic plants infected by fungi of the Order Uredinales. Sampling was carried out on several roads and trails of the park and from environmentally protected areas around it at altidudes between 500 and 2600 MSL. Collected material was herborized and taken to the Mycology Laboratory of the Instituto de Pesquisas Jardim Botânico do Rio de Janeiro for definitive identification of both host and rust.

To prepare samples for observation under a Leica S6E stereomicroscope, free-hand sections and scrapings were placed into lactophenol and chloral hydrate. Rust structure was observed using a Zeiss Axioskop 40 microscope connected to a Zeiss Axiocam MRC digital camera. Images and spore measurements were performed using the Axiovision Rel 4.6 program. Rusts were identified through morphology, spectrum of hosts and comparisons with specialized Uredinales literature.

The database of the Instituto de Pesquisas Jardim Botânico do Rio de Janeiro Herbarium (JABOT) was consulted to determine some host/rust relationships. This database is the most reliable and complete bank of information concerning plants from PARNA Itatiaia. Ten botanical families with the greatest number of vascular species in the park were chosen and their rust/host relationship calculated.

For the analysis of altitudinal distribution of Uredinales, the system of physiognomic-ecological classification, as described by Veloso *et al*. (1991), was adopted. Based on this system, park vegetation was divided into two distinct altitudinal areas: one between 500-1500 MSL and other above 1500 MSL. The similarity between these two areas was determined by means of the presence/absence of species using the Sørensen coefficient (Allegrucci *et al*. 2007, Marques *et al*. 2008), as follows: Sø=2a/b+c, where "b" and "c" are the number of species in each area and "a" is the number of species common to both areas. This index ranges from 0 (no similarity-Absence) to 1 (complete similarity-Presence). The same coefficient was applied to the comparative study between the PARNA Uredinales Biota and the Colombian Coffee Region located in the Colombian Andes at an altitude of 1000-2000 MSL (Salazar 2002).

RESULTS AND DISCUSSION

Composition

Uredinales. The Biota of Uredinales (rust fungi) in the Parque Nacional do Itatiaia is composed of 38 genera (32 teleomorphs and 6 anamorphs), representing 28% of the genera recognized worldwide (Cummins & Hiratsuka; 2003). Two hundred and seven species of Uredinales were found in the park, out of which 178 were teleomorphs and 29 anamorphs, representing almost 28% of all known species of Brazil. Nine are new records for Brazil, and 171 species are new records for the park. Moreover, one genus, 12 teleomorphic species and 11 anamorphic species are new to science (Figure 1).

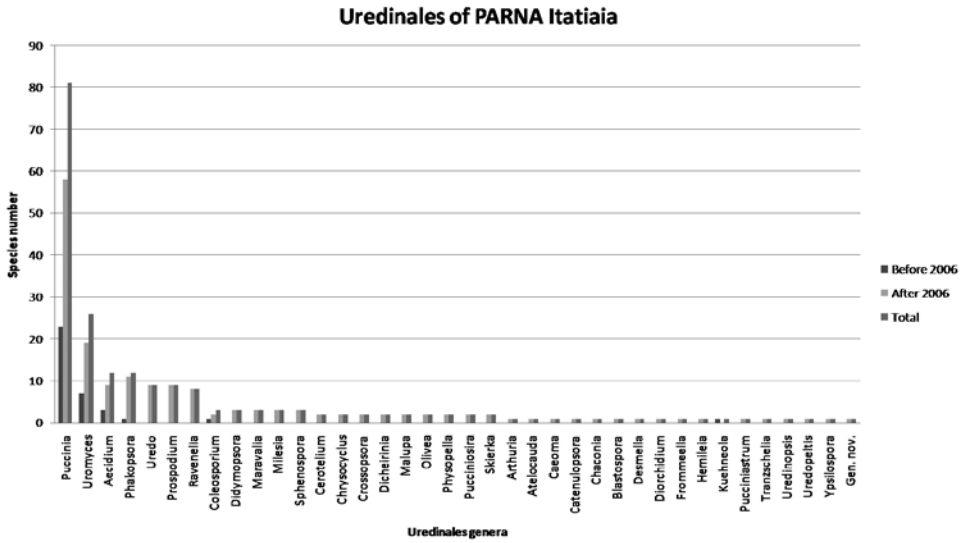

Figure 1. Composition of Uredinales Biota from PARNA Itatiaia.

Sixty-one percent of the species at PARNA Itatiaia were found in Minas Gerais; 19% (39 species) were unique to this State. Of these species, 12 were found in the environmentally protected area around the park. Thirty-one new records were registered for the Uredinales Biota of Minas Gerais. Rio de Janeiro comprises 81% species of the rust fungi at PARNA Itatiaia. Thirty-nine percent (81 species) are exclusive to this State. Of 168 species collected in Rio de Janeiro State, 34 correspond to new records for PARNA Itatiaia. Eighty-one species (42%) are common to both Minas Gerais and Rio de Janeiro States.

Several rusts of economic importance were found at PARNA Itatiaia (Table 1). These fungi were collected from native and exotic plants that have been commercialized. Some of these plants and their parasitic diseases are already widespread, suggesting that the park could be a source of inocula for cultures of significant economic importance that will eventually be established around it.

Seven species previously reported were not collected again: *Aecidium eupatorii*, *Puccinia improvisa*, *Puccinia itatiayensis*, *Puccinia lorentzii*, *Puccinia millegranae*, *Uromyces cisneroanus* and *Uromyces dolichosporus*.

Hosts. The coevolutionary relationship between Uredinales and their hosts has been discussed in some studies of neotropical rusts (Buriticá 2000, Cummins & Hiratsuka 2003, Pardo-Cardona 2000, Salazar *et al*. 2002, Smith & Coil 2007). Thus, both knowledge and correct identification of the hosts are essential to studies of Uredinales. At PARNA Itatiaia, 192 hosts belonging to 63 families were recorded. Considering the limitation of previous identifications, 105 species are new records of hosts from the Brazilian Uredinales Biota. This fact shows the importance of collaboration between mycologists, botanists and plant pathologists in contributing to our overall understanding of biodiversity.

Eleven genera belonging to four families of Pteridophyta were identified as parasitized by 4 (2%) species of rusts. In Liliopsida, 13 families and 33 genera were identified as parasitized by 35 (17%) species of Uredinales. Magnoliopsida presented 43 families and 135

Table 1. Rusts of economic importance collected in PARNA Itatiaia

Rust species	Host species	Culture of economic importance
Hemileia vastatrix	*Coffea arabica* L.	Coffee
Phakopsora meibomiae	*Desmodium uncinatum* (Jacq.) DC	Soybean
	Desmodium sp.	
Puccinia coronata	*Polypogon elongatum* H.B.K.	Grasses
	Brachiaria sp.	Brachiaria
Puccinia levis	*Paspalum pilosum* Lamark.	
	Paspalum sp.	
Puccinia psidii	*Myrcia hirsuta* O. Berg.	Myrtaceous species
	Myrcia splendens (Sw.) DC	
	Myrcia sp.	
	Psidium guajava L.	
	Syzygium jambos (L.) Alston	
	Myrtaceae indet.	
Puccinia thaliae	*Canna paniculata* Ruiz et Pavon	Cannas and Calatheas
	Canna sp.	
	Calathea sp.	
Puccinia recondita	*Briza calotheca* (Trin.) Hack.	Wheat
Tranzschelia discolor	*Prunus persica* L.	Peach
Uredo anthuri	*Anthurium minarum* Sakuragui and Mayo	Aroids
	Anthurium sp.	
Uromyces alstroemeriae	*Alstroemeria foliosa* Mart.	Peruvian lily
	Alstroemeria isabellina Herbert	
	Alstroemeria sp.	
Uromyces transversalis	*Gladiolus* sp.	Gladiolus

genera parasitized by 168 (81%) rust species (Table 2). At the park, 67% of host families recorded by Hennen *et al*. (2005) for Brazil were found, indicating the importance of this rust biota.

The host families with the greatest number of rust species were *Asteraceae* with 42 species (20%), *Leguminosae* with 24 species (11%) and *Poaceae* with 18 species (9%), representing 40% of all species present in the park (Table 3). These results corroborate the pattern suggested by Hennen *et al*. (2005) in Brazil. In Colombia Pardo-Cardona (2000), the same three families with 33% of species were indicated, with *Asteraceae* the most numerous in species, followed by *Poaceae* and *Leguminosae*.

Table 2. Number of hosts taxa parazitized by Uredinales at PARNA Itatiaia

Taxa	Botanical families	Botanical genera	Uredinales species
Pteridophyta	7	11	4
Liliopsida	13	33	35
Magnoliopsida	43	135	168
Total	63	179	207

Using JABOT data to establish rust:host relationships, the family *Orchidaceae* appeared to be the second greatest family (9%) in number of species in the park. However, out of 173 species of *Orchidaceae* already registered in the park, only one rust was identified, thus presenting a very low rust: host relationship (1:173). A similar result was found by Berndt (2008) in South Africa. Out of the 10 most numerous families, 4 had no records at all for rusts, and the family with the greatest number of species, *Aizoaceae* (2592 species), had only 9 species of Uredinales and a correspondingly low rust:host ratio (1:288). Even the rust:host ratio for the 10 richest families in species from South Africa was 1:47 (Berndt 2008), which is low, when compared to 1:8 of PARNA Itatiaia (Table 3).

The Biota of the Uredinales from PARNA Itatiaia represents almost 28% of species recorded from Brazil, confirming again its great biological diversity. The importance of preserving both hosts and parasites is well established, as, theoretically, these organisms exert a mutually inclusive pressure to maintain the dynamic balance so necessary in natural

areas. Additionally, the rust:host relationship contributes to the speciation of both. The knowledge of the biota of rusts is, therefore, very useful in policy design for biodiversity management and conservation.

Table 3. Number of Uredinales species in the most representative families of PARNA Itatiaia and rust/host relationship

Families	Number of botanical species*	Number of Uredinales**	Rust/Host Relationship
Asteraceae	218	42	1:5
Orchidaceae	173	1	1:173
Leguminosae	154	24	1:6
Myrtaceae	96	2	1:48
Rubiaceae	73	8	1:9
Piperaceae	65	2	1:33
Solanaceae	62	6	1:10
Poaceae	42	18	1:2
Euphorbiaceae	31	8	1:4
Cyperaceae	29	5	1:6
Total	943	116	1:8

* Data from JABOT Jan/2009 (RB - Herbarium of Instituto de Pesquisas Jardim Botânico do Rio de Janeiro), ** data from this study

Diversity of species

The genera *Puccinia* (with 81 species), *Uromyces* (with 26), *Aecidium* (12) and *Phakopsora* (12) had the highest number of species (Figure 2). The first had 39% of species, followed by *Uromyces* with 13% and *Aecidium* and *Phakopsora* with 6% each. As such, 64% of park species belong to 3 teleomorphic genera and one anamorphic genus. The number of *Puccinia* species previously recorded in the park was 23. After our new collections, the number rose to 81, an increment of 352%. The genus *Uromyces* increased from 7 to 26 species (371%), *Aecidium* from 3 to 12 species (400%) and *Phakopsora* from 1 to 12 (1200%).

Until 2006, the Biota of Uredinales from Brazil was composed of 56 teleomorphs, 9 anamorphs and about 745 species (Hennen *et al*. 2005). In the same catalogue, the species of the teleomorphic genera *Puccinia*, *Uromyces* and *Phakopsora* represented 54% of occurrences, while the anamorphs *Aecidium* and *Uredo* accounted for 19%. Table 4 shows a comparison between the Uredinales Biota from PARNA Itatiaia and three locations in the Atlantic Forest and Cerrado from São Paulo State (Carvalho-Jr. 2001, Carvalho-Jr. *et al*. 2004, 2008). These studies show almost the same pattern when compared to Hennen *et al*. (2005). At PARNA Itatiaia, species of *Puccinia*, *Uromyces* and *Phakopsora*

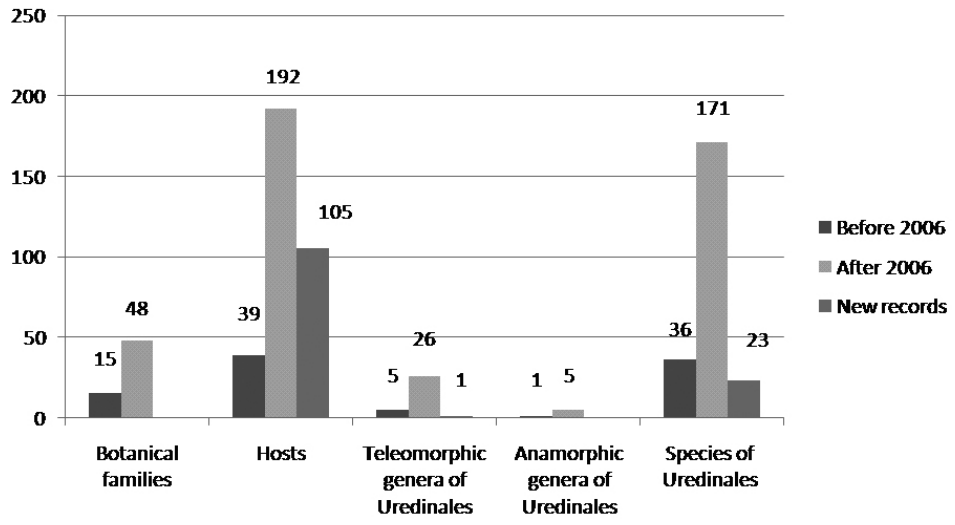

Figure 2. Number of species per genus of Uredinales in the PARNA Itatiaia.

represented 58% of occurrences. Thus, for the Atlantic Forest region, the species percentages of these three genera vary from 58 to 65% (Table 4), depending on the studied locality. On the other hand, in São Paulo State Cerrado areas, these three genera account for 51% of occurrences.

The anamorphic genera *Aecidium* and *Uredo* from the park correspond to 10% of species, a number slightly below the data reported by Hennen *et al.* (2005) (all data from Brazil). In the present study, the anamorphic genera *Caeoma*, *Milesia*, *Malupa* and *Physopella* are reported for the first time at PARNA Itatiaia and comprise15% of the total species. This value would be even greater if we were to consider the teleomorphic species with unknown life cycle. Therefore, further studies aimed at the characterization of the life cycles of rust fungi in the park are suggested.

The five teleomorphic genera with the largest number of species at PARNA Itatiaia and other tropical regions, such as Brazil, Colombia, Costa Rica, southern Africa (Botswana, Namibia and South Africa) and Taiwan, are shown in Table 5. The genera *Puccinia*, *Uromyces* and *Phakopsora* comprise between 45% and 64% of the 5000 to 7000 species reported by Cummins & Hiratsuka (2003). In southern Africa, Berndt (2008) reports *Uromyces* and *Puccinia* with 59% of occurrences and considers *Phakopsora* well represented with 1% of occurrences. In the present study, *Phakopsora* represented 6% of species. This value reflects experience gained in recent years on species of this genus based on various studies developed in the Neotropics, including the work of Buriticá (1994, 1999), Buriticá & Pardo-Cardona (1996), Dianese *et al*. (1993), Ono *et al*. (1992), Ono (2000) and Salazar & Carvalho-Jr. (2009). According to Cummins & Hiratsuka (2003), *Phakopsora* is one of the largest genera in the humid regions of the tropics. The study of this teleomorph requires some experience because the telial sori are subepidermal or subcuticular, and symptoms are difficult to find. Consequently, *Phakopsora* species are often identified only as *Uredo*.

Hennen & McCain (1993) proposed that the rate of rust fungi to host plants in a given area generally ranges between 5%, or 1:20 and 25%, or 1:4. Their results were based on estimates of the number of rust species in some Central American countries and data from Mogi Mirim (Brazil) and Indiana (USA). Based on this standard and using a rust:host estimate of 1:20 (5%), we would calculate 99 species of rust fungi in the park (Table 5). However, this number represents 48% fewer species than were actually found in the present study. On the other hand, applying a 1:4 (25%) ratio, the estimated number of rusts would be

Table 4. Number of species by genus with larger number of species from PARNA Itatiaia and other areas of Atlantic Forest and Cerrado

Genera	PARNA Itatiaia n(%)[a]	Forest Reserve Armando de Salles Oliveira-SP n(%)[b]	Parque Estadual das Fontes do Ipiranga-SP n(%)[c]	Cerrado-SP n(%)[d]
Puccinia	81(39)	15(36)	35(49)	53(33)
Uromyces	26(13)	7(17)	7(9)	19(12)
Phakopsora	12(6)	5(12)	5(7)	10(6)
Prospodium	9(4)	--	--	5(3)
Ravenelia	8(4)	2(4)	3(4)	8(5)
Coleosporium	3(1)	2(4)	3(4)	4(2)
Didymopsora	3(1)	--	--	--
Aecidium	12(6)	1(2)	2(2)	10(6)
Uredo	9(4)	1(2)	4(5)	6(4)
Total of species	**207**	**41**	**71**	**157**

[a]Data from this study; [b]Carvalho-Jr. (2001); [c]Carvalho-Jr. *et al.* (2004); [d]Carvalho-Jr. *et al.* (2008)

493 species, out of which only 42% would be known. Brazil would then have 5% of known species, Colombia 3%, Costa Rica 9%, South Africa 10% and Taiwan 45%. Based on our study, the rust:host relationship found in the park is actually 1:9 (Table 5), meaning that 11% of vascular species of the park are infected by rusts. The collections made for this study were comprehensive, and the sampling represents almost all species of rusts known in that biota. Therefore, when our 1:9 ratio, which is intermediate, is compared with the estimates of Hennen & McCain (1993), we believe that this estimate is closer to reality and can be applied to other tropical regions. Thus, if we then go one step further and apply the rust:host relationship of 1:9, as calculated for PARNA Itatiaia, to Brazil, as a whole, the number of rusts would be 6246 (Table 5), out of which only 12% of rust species would be known in the country. Using the same method, we would find Colombia to have 5691 species, with only 7% having been collected, and Costa Rica would have 1346 species, but only 22% would be currently recorded. Finally, in the whole of southern Africa, including Namibia, Botswana and South Africa, the estimate would be 2333 species, from which only 23% would be known. By these estimates, countries like Brazil and Colombia, as depositories of a great diversity of plants (www.earthtrends.wri.org/searchable_db), also apparently have a great diversity of unknown rust fungi.

Altitudinal distribution

The altitudinal distribution of Uredinales species at PARNA Itatiaia (Table 6) showed some variation between *Floresta Ombrófila Densa Montana*, (500-1500 MSL) and *Floresta Ombrófila Densa Alto-Montana* (above 1500 MSL). However, the teleomorphs *Uromyces* and *Puccinia* and the anamorphs *Aecidium* and *Uredo* were widely distributed over the entire altitudinal profile of the park and, in general, include species with the highest number of occurrence (Figure 2). These results are similar to those found in the Colombian Andean mountains with altitudes varying from 0 m to >3000 m (Pardo-Cardona 2000).

Furthermore, among the physiognomic-ecological profiles of PARNA Itatiaia, several altitude specializations were found (Table 6). Species of several genera, including *Caeoma*, *Catenulopsora*, *Cerotelium, Blastospora*, *Dicheirinia*, *Diorchidium*, *Hemileia*, *Milesina*, *Physopella*, *Ravenelia*, *Skierka*, *Sphenospora*, *Uredopeltis*, *Ypsilospora*, and one new genus, were only found in the *Floresta Ombrófila Densa Montana* (500-1500 MSL). At this altitude, 175 Uredinales species were found,

Table 5. Diversity of rusts in PARNA Itatiaia and other tropical regions

Teleomorphic genera	PARNA Itatiaia n(%)[a]	Brazil n(%)[b]	Colombia n(%)[c]	Costa Rica n(%)[d]	southern Africa n(%)[d]	Taiwan n(%)[d]
Puccinia	81(39)	264(35)	204(47)	136(45)	217(40)	140(32)
Uromyces	26(13)	107(14)	51(11)	39(13)	103(19)	37(8)
Phakopsora	12(6)	28(3)	14(3)	11(4)	8(5)	23(5)
Prospodium	9(4)	31(4)	7(2)	10(3)	--	--
Ravenelia	8(4)	41(5)	5(1)	13(4)	27(5)	6(1)
Total of species	207	745	428	300	546	442
Number of vascular species	1975[1]	56.215[2]	51.220[2]	12.119	21000	3897
Rust/Host relationship	1:9,5	1:75	1:119	1:40	1:39	1:9
Rust estimate						
1:20	99	2811	2561	605	1050	195
1:4	493	14053	12805	3029	5250	974
1:9	207	6246	5691	1346	2333	442

[a]Data from this work; [b]Hennen *et al.* (2005); [c]Buriticá *et al.* (2009) (inedit); [d]Berndt (2008); [1]Data JABOT; [2]World Resources Institute (www.earthtrends.wri.org/searchable_db).

representing 84% of the Uredinales Biota in the park.

Ravenelia species, which have *Leguminosae* as host specificity, represented one of the highest numbers of occurrences; however, they were only found in the areas of *Floresta Ombrófila Densa Montana* (500-1500 MSL). This fact probably results from the presence of both shrub and tree legumes, predominantly at an altitude ranging from 700 to about 1200 MSL (Morim & Barroso 2007); consequently, species of *Ravenelia* are also predominantly in this region.

The genera *Atelocauda*, *Frommeella* and *Pucciniastrum*, which are represented by one species each (Table 6), were only found in the *Floresta Ombrófila Densa Alto-Montana* (> 1500 MSL). *Frommeella* and *Pucciniastrum* were only found above 1950 MSL, the natural habitat of their hosts. In *Floresta Ombrófila Densa Alto-Montana*, 101 Uredinales species were collected, representing 49% of species in the PARNA Itatiaia.

Similarity between PARNA Itatiaia and the Colombian Coffee Region at equivalent altitudinal ranges was only 26% (Table 7). Most species were exclusive to each region, and those in common were species of wide geographical distribution, such as *Hemileia vastatrix*, *Puccinia cnici-oleracei*, *Puccinia hydrocotyles*, *Puccinia oxalidis*, *Uromyces setariae-italicae* and *Uromyces tenuicutis*, among others.

At genus level, Safford (1999) found evidence of biogeographical relationships among plants, birds, frogs, butterflies, beetles and hymenoptera in fields of the same altitude in southeastern Brazil and similar habitats of the Andes. In spite such biogeographical relationships in these regions (Safford 1999, 2007), the distribution of species is highly endemic (Safford 1999, Fernández-Alonso 2003). With 26% similarity of Uredinales between these two regions, this value probably reflects differences in climatic factors, topography, latitude and plant species, as well as the restricted distribution of their hosts.

The Sørensen coefficient was small when diversity at Itatiaia was compared to similar regions in the Colombian Andes (Table 7). Similarity between different altitudinal

Table 6. Distribution of genera of Uredinales and number of species (in parentheses) in the two physiognomic-ecological areas in the PARNA Itatiaia.

Between 500-1500 m	Above 1500 m	Total of species
Aecidium (8)	*Aecidium* (8)	12
Arthuria (1)	*Arthuria* (1)	1
	Atelocauda (1)	1
Caeoma (1)		1
Catenulopsora (1)		1
Cerotelium (2)		2
Chaconia (1)	*Chaconia* (1)	1
Chrysocyclus (1)	*Chrysocyclus* (2)	2
Coleosporium (3)	*Coleosporium* (1)	3
Crossopsora (1)	*Crossopsora* (2)	2
Blastospora (1)		1
Desmella (1)	*Desmella* (1)	1
Dicheirinia (2)		2
Didymopsora (3)	*Didymopsora* (2)	3
Diorchidium (1)		1
	Frommeella (1)	1
Hemileia (1)		1
Kuehneola (1)	*Kuehneola* (1)	1
Malupa (2)	*Malupa* (1)	2
Maravalia (3)	*Maravalia* (1)	3
Milesia (3)		3
Olivea (2)	*Olivea* (1)	2
Phakopsora (11)	*Phakopsora* (3)	12
Physopella (2)		2
Prospodium (7)	*Prospodium* (2)	9
Puccinia (66)	*Puccinia* (49)	81
	Pucciniastrum (1)	1
Pucciniosira (2)	*Pucciniosira* (2)	2
Ravenelia (8)		8
Skierka (2)		2
Sphenospora (3)		3
Tranzschelia (1)	*Tranzschelia* (1)	1
Uredinopsis (1)	*Uredinopsis* (1)	1
Uredo (8)	*Uredo* (3)	9
Uredopeltis (1)		1
Uromyces (22)	*Uromyces* (14)	26
Ypsilospora (1)		1
Gen. nov. (1)		1
Total espécies		207

ranges at Itatiaia (500-1500 MSL and > 1500 MSL) was high at 0.502. This value can be explained by the presence of cosmopolitan species in both forest formations and the broad area of transition between the two forest formations suggested by Veloso *et al*. (1991). By way of comparison, similarity between the same altitudinal ranges in the Colombian Andes gave a higher value of 0.701, as a likely consequence of differences in latitude, topography and the greater extension of the Colombian forest formation.

Table 7. Matrix of association from the Sørensen coefficient, between the rusts of PARNA Itatiaia (BR) and the Colombian Coffee region (Andes), considering the altitudinal ranges of Veloso *et al*. (1991)

	BR 500-1500	BR 1500-	COL 500-1500	COL 1500-
Itatiaia (BR) 500-1500 m	1			
Itatiaia (BR) > 1500-	0,502	1		
Andes (COL) 500-1500 m	0,274	0,21	1	
Andes (COL) > 1500-	0,296	0,26	0,701	1

CONCLUSIONS

PARNA Itatiaia has approximately 28% of the currently known Uredinales species of Brazil. This diversity is represented by 38 genera and 207 species of Uredinales parasitizing hosts of 63 botanical families and 179 genera. Thirty-one new occurrences of Uredinales Biota were registered for Minas Gerais and 34 for Rio de Janeiro. A total of 201 novel species, genera, hosts and records for Brazil in the States of Minas Gerais and Rio de Janeiro were reported. Thus, for every 6 samples collected, labeled and incorporated into the Herbarium (1157/201), one brings new information.

With respect to the geographical distribution of species found at the park, 37% of species (77) are restricted to Brazil, and 54% of species (111) can be found in at least two countries on the American continent. The remaining 9% (19) are distributed worldwide. In PARNA Itatiaia, several altitude specializations were found. Some species were only found between 500-1500 MSL, while others were only present at altitudes higher than 1500 MSL, according to the natural habitat of their hosts.

The similarity of Uredinales species between the two altitudinal extracts in the same region may be considered high: 50% (PARNA Itatiaia) and 70% (Colombian Coffee Region). However, the similarity between these two regions is low (26%), probably as a result of marked differences in climate, topography, latitude and plant species.

Several native and exotic plants of economic importance are parasitized with Uredinales in the park and could act as a permanent source of inocula for crops cultivated nearby, such as coffee, soybeans, brachiaria, cannas and calatheas and Peruvian Lily, among others.

Overall, considering the uncontrolled deforestation of the Atlantic Forest and other hotspot regions and also the sparse research and the scarce resources available for research, many new species of rust will never be known.

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